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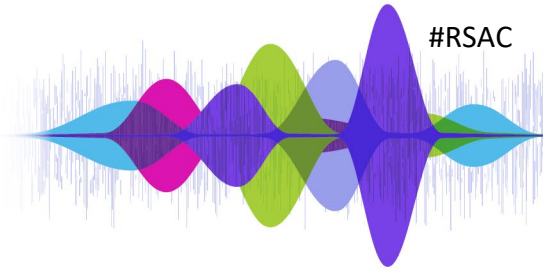
SESSION ID: USENIX-M05A

Terrapin Attack: Breaking SSH Channel Integrity by Sequence Number Manipulation

Fabian Bäumer

Research Assistant
Ruhr University Bochum



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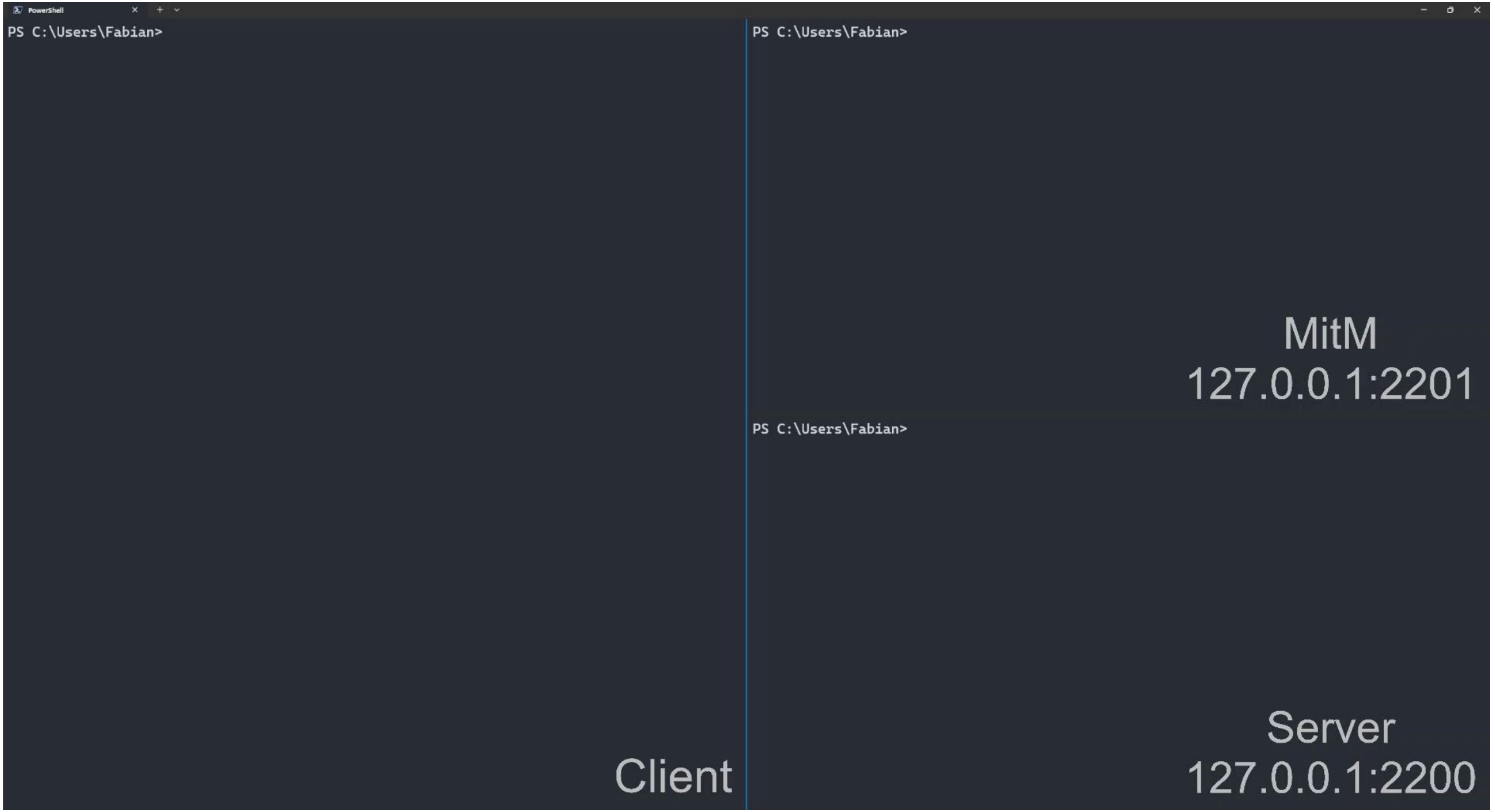
PowerShell
PS C:\Users\Fabian>
PS C:\Users\Fabian>
MitM
127.0.0.1:2201
PS C:\Users\Fabian>
Client
Server
127.0.0.1:2200

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The Secure Shell (SSH) Protocol

SSH Is Split Into Separate Layers

SSH Connection Protocol [RFC4254]

SSH Authentication Protocol [RFC4252]

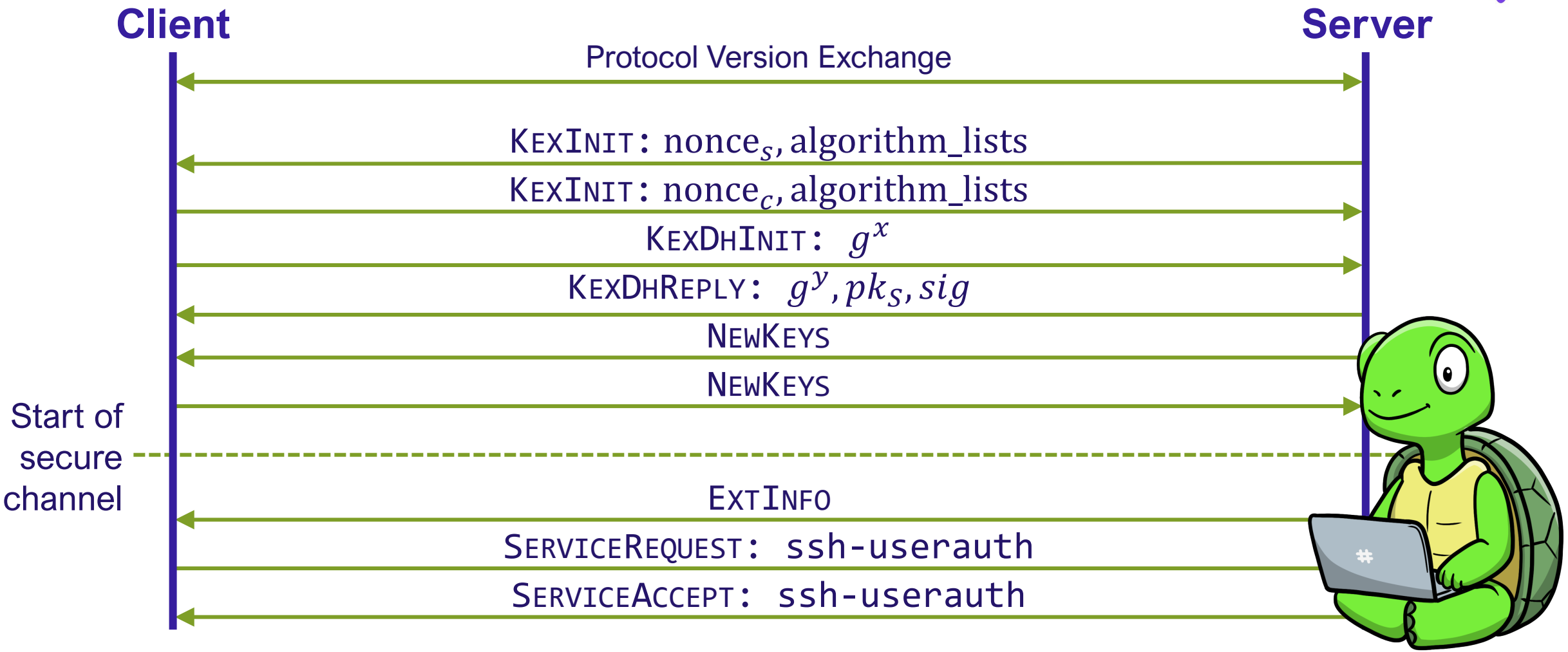
SSH Transport Layer Protocol (TLP) [RFC4253]

=> Binary Packet Protocol

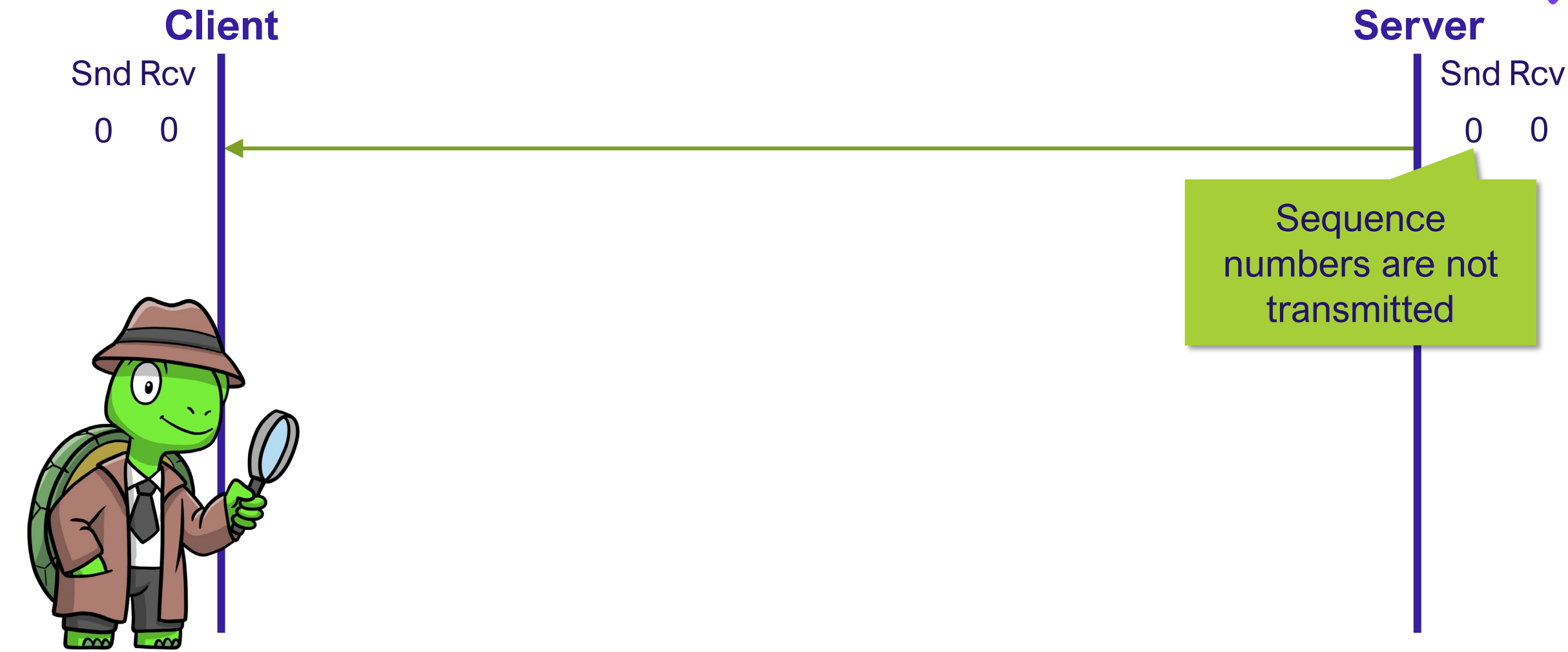
=> SSH Handshake

TCP / IP

A Typical SSH Handshake



SSH Uses Implicit Sequence Numbers



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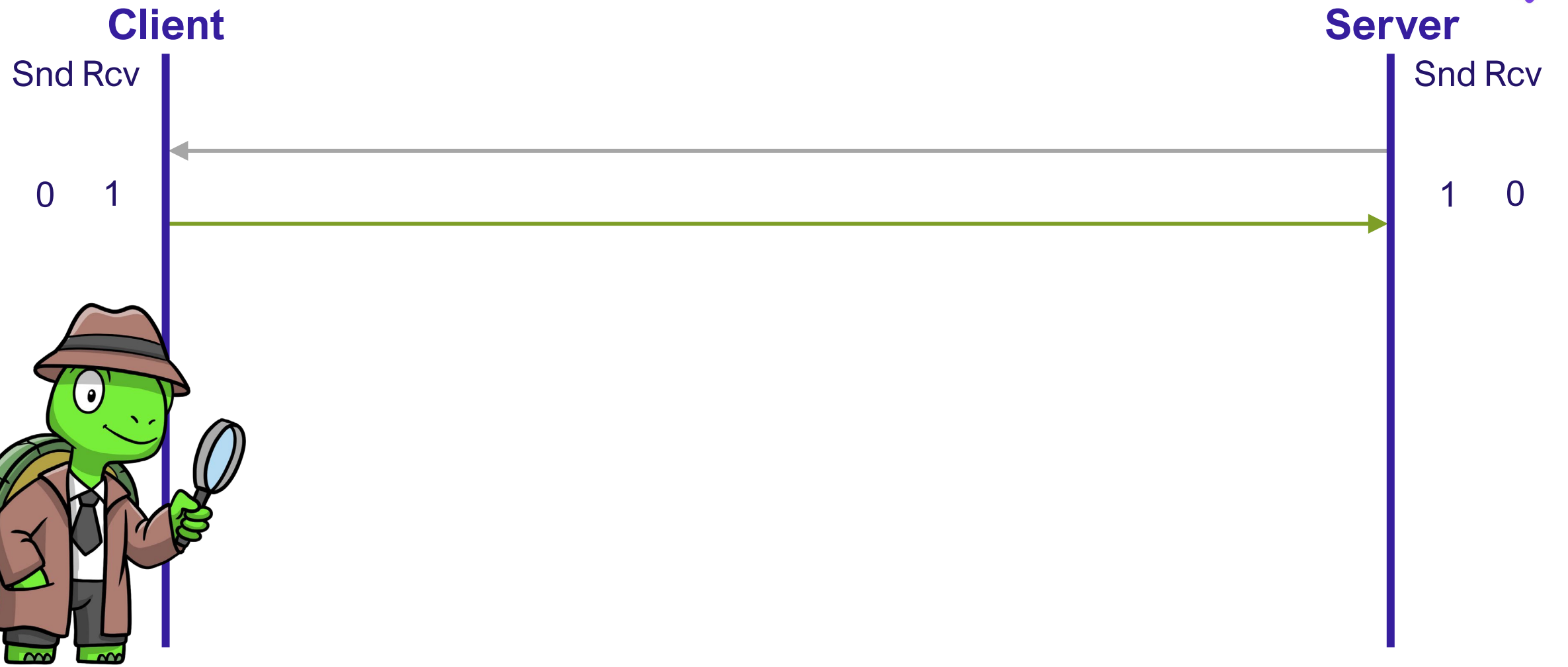

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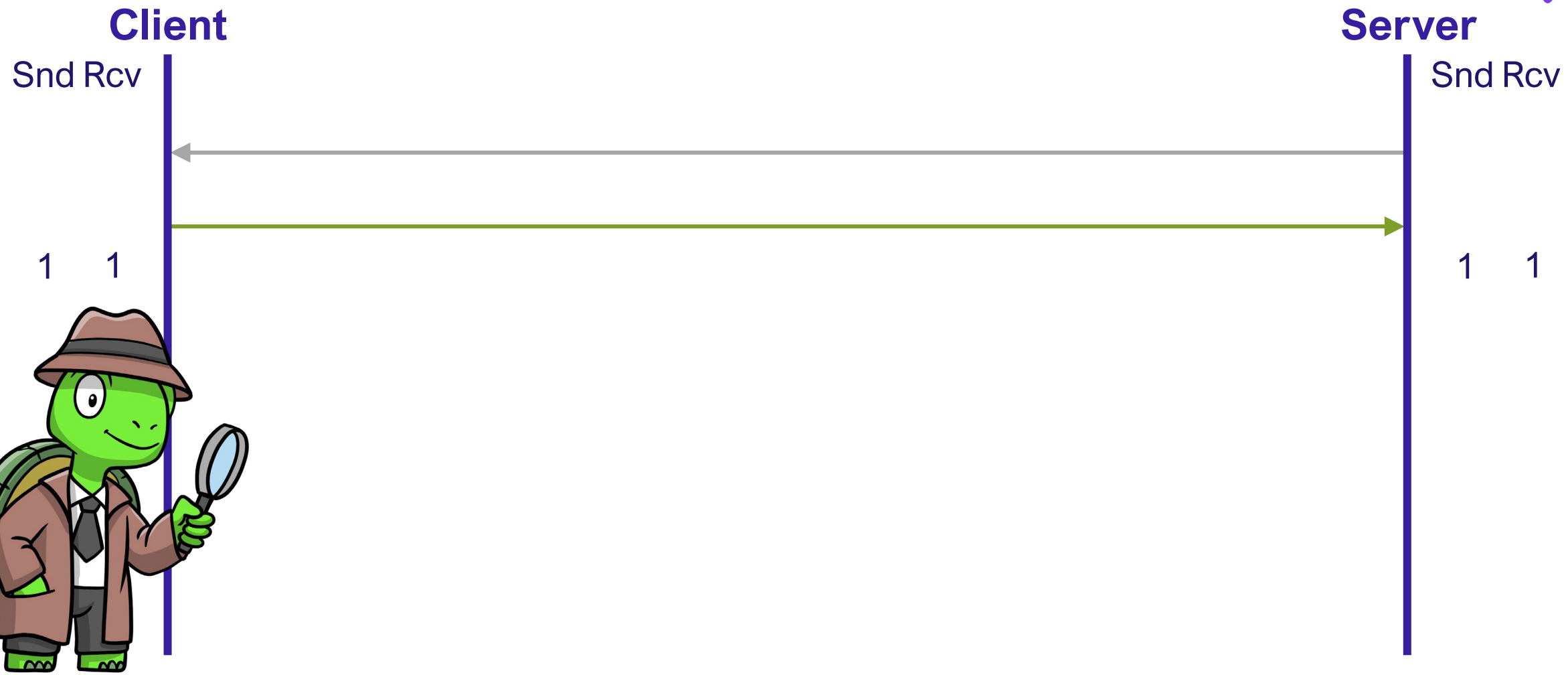

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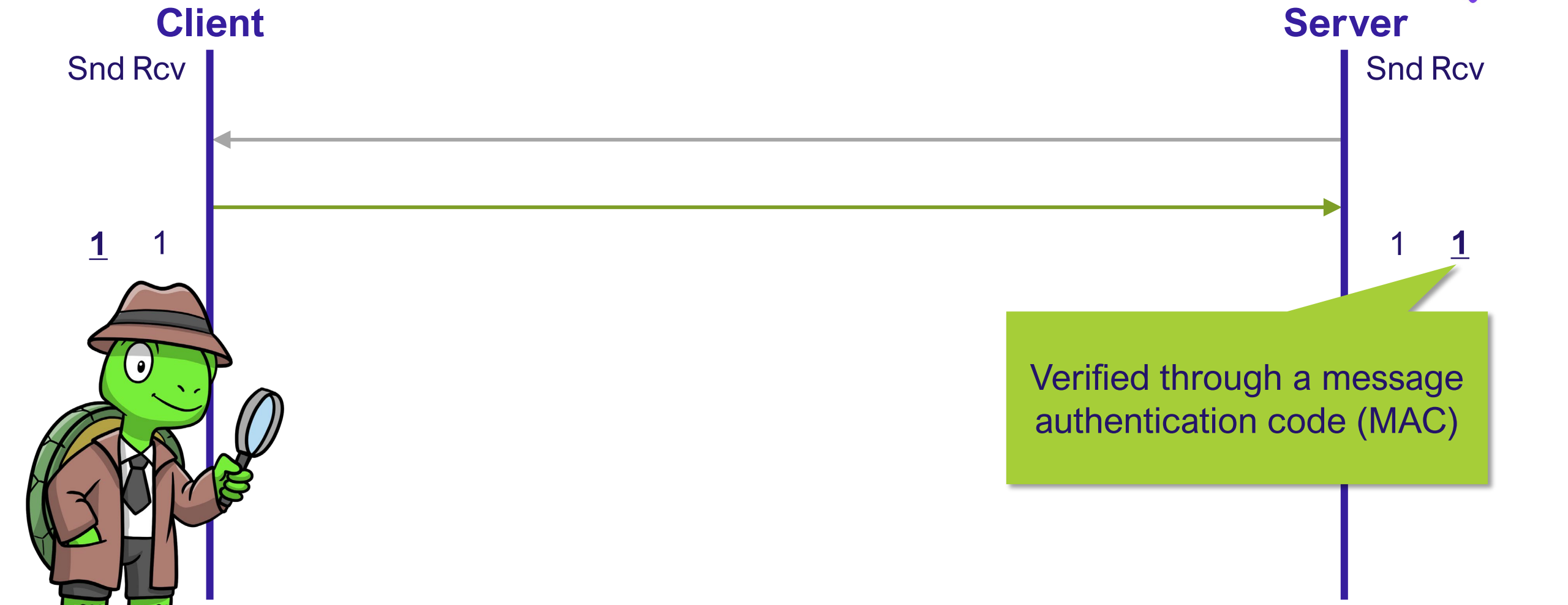
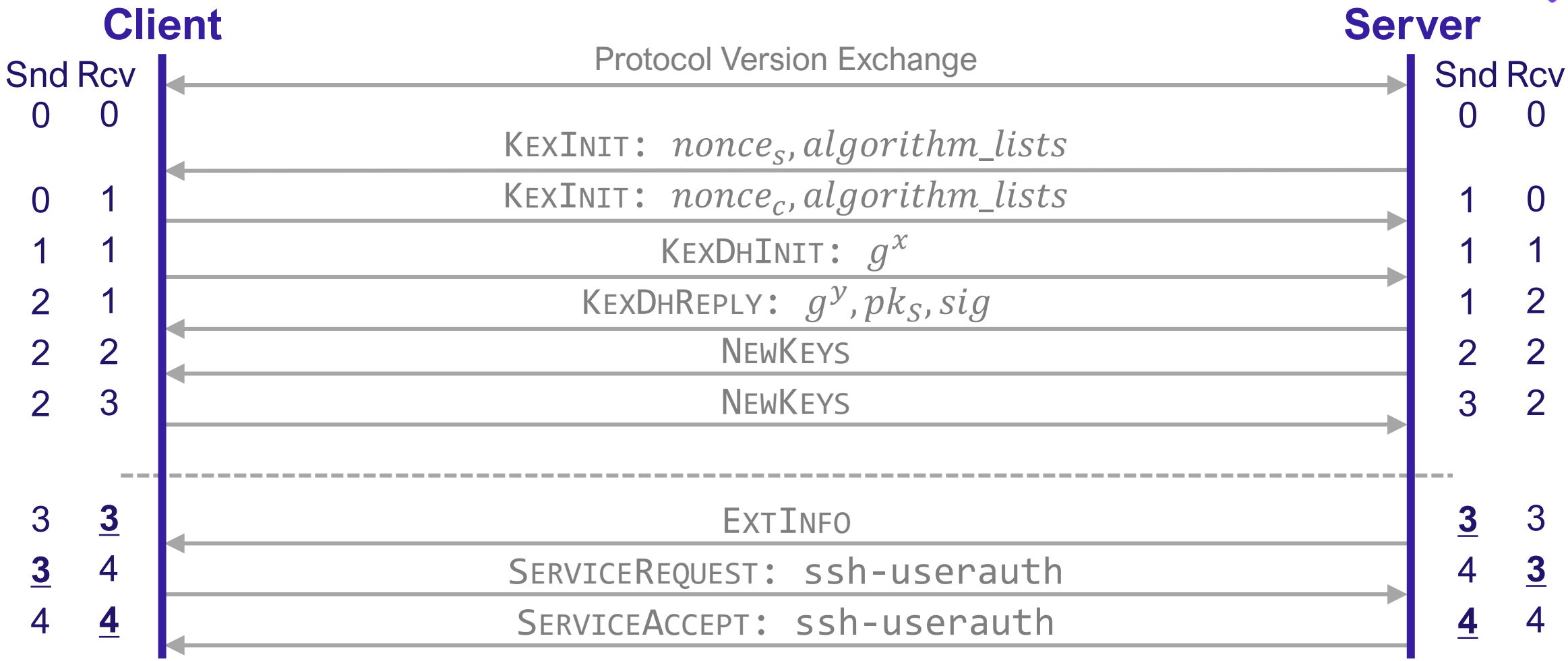


Introducing Sequence Numbers to the Flow



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The Terrapin Attack

CVE-2023-48795
(CVE-2024-41909)

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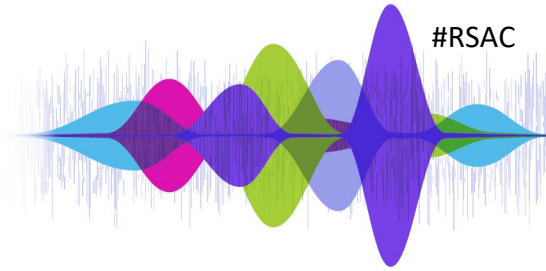
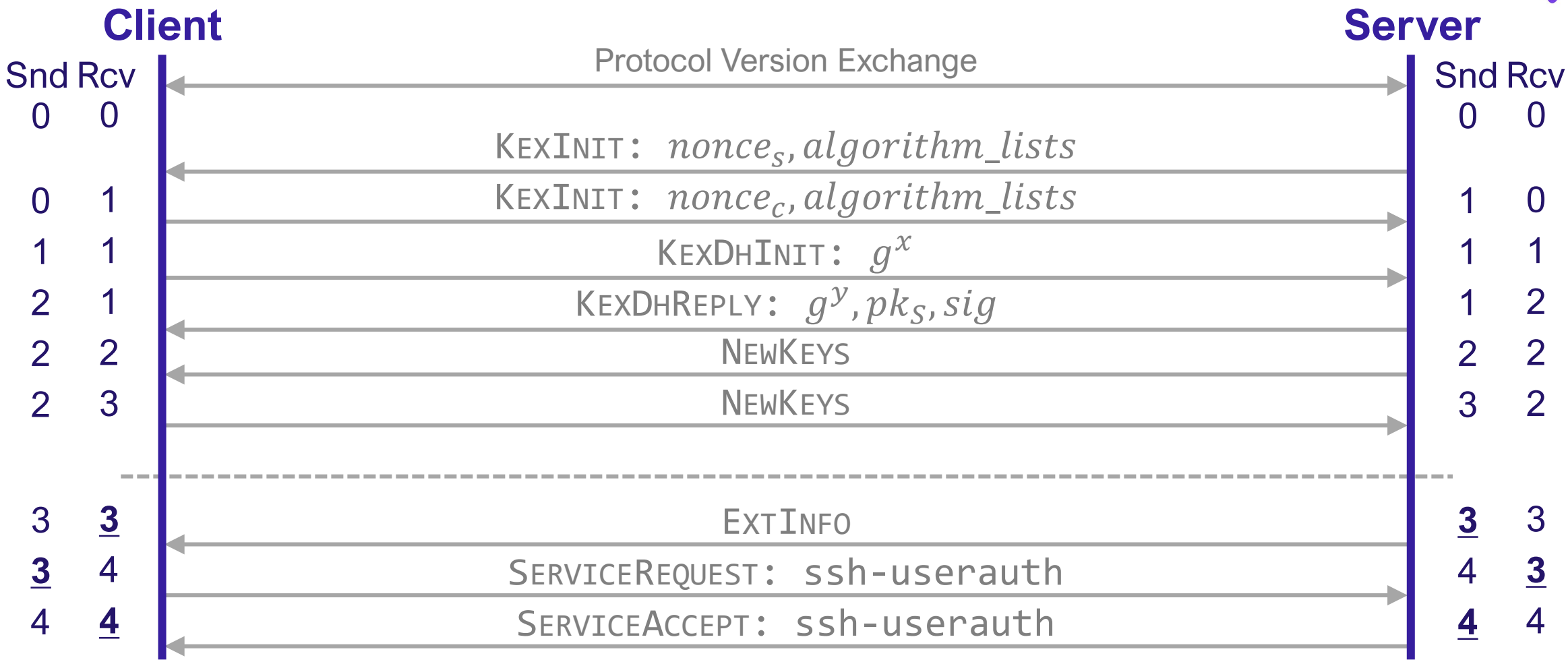
SSH Allows for Optional Messages in Handshakes





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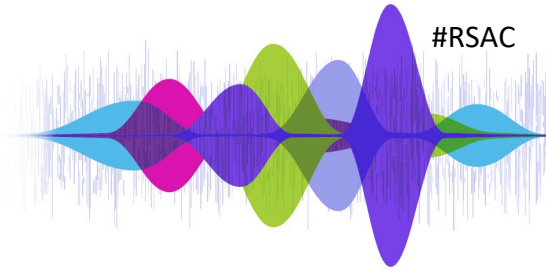

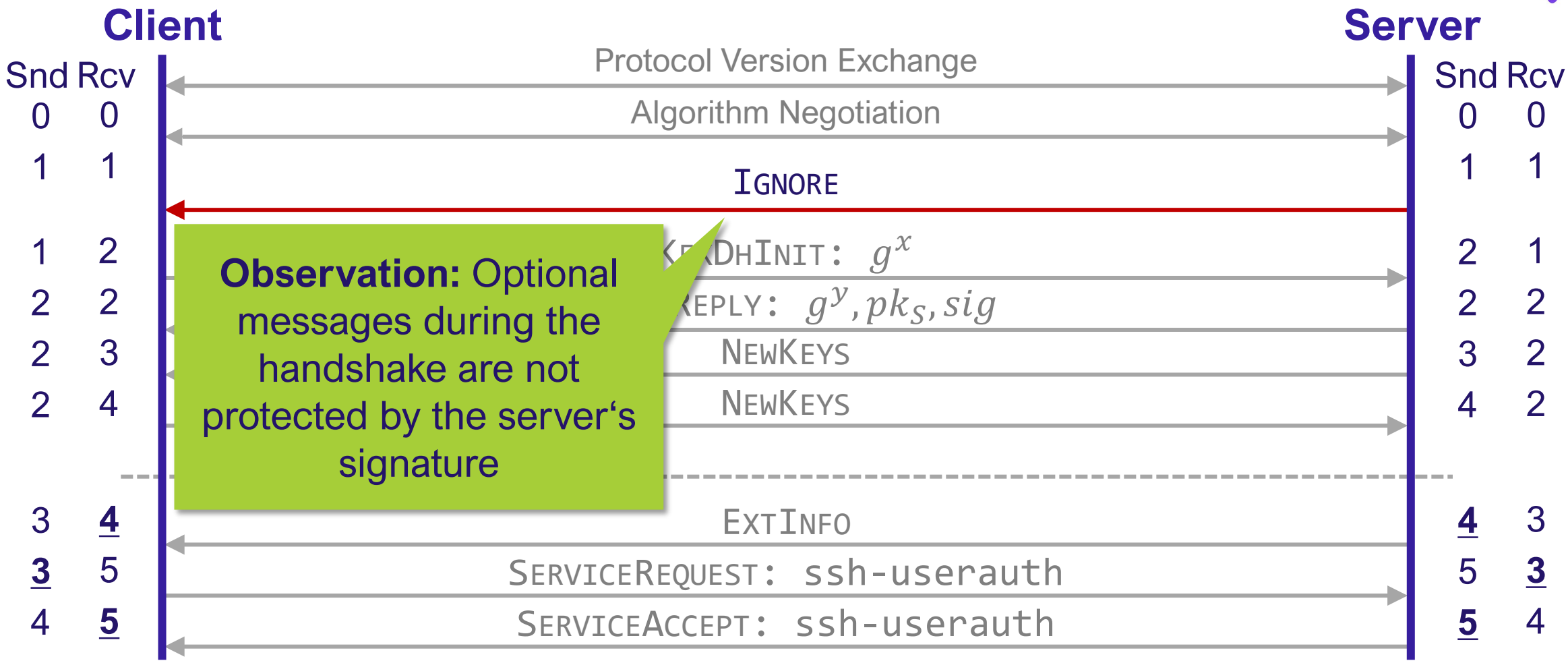

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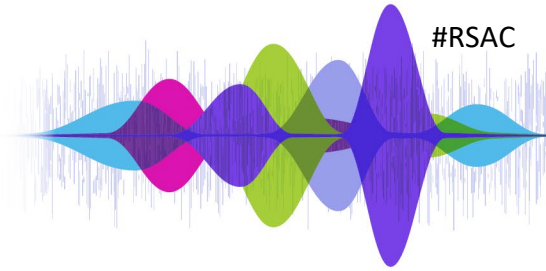
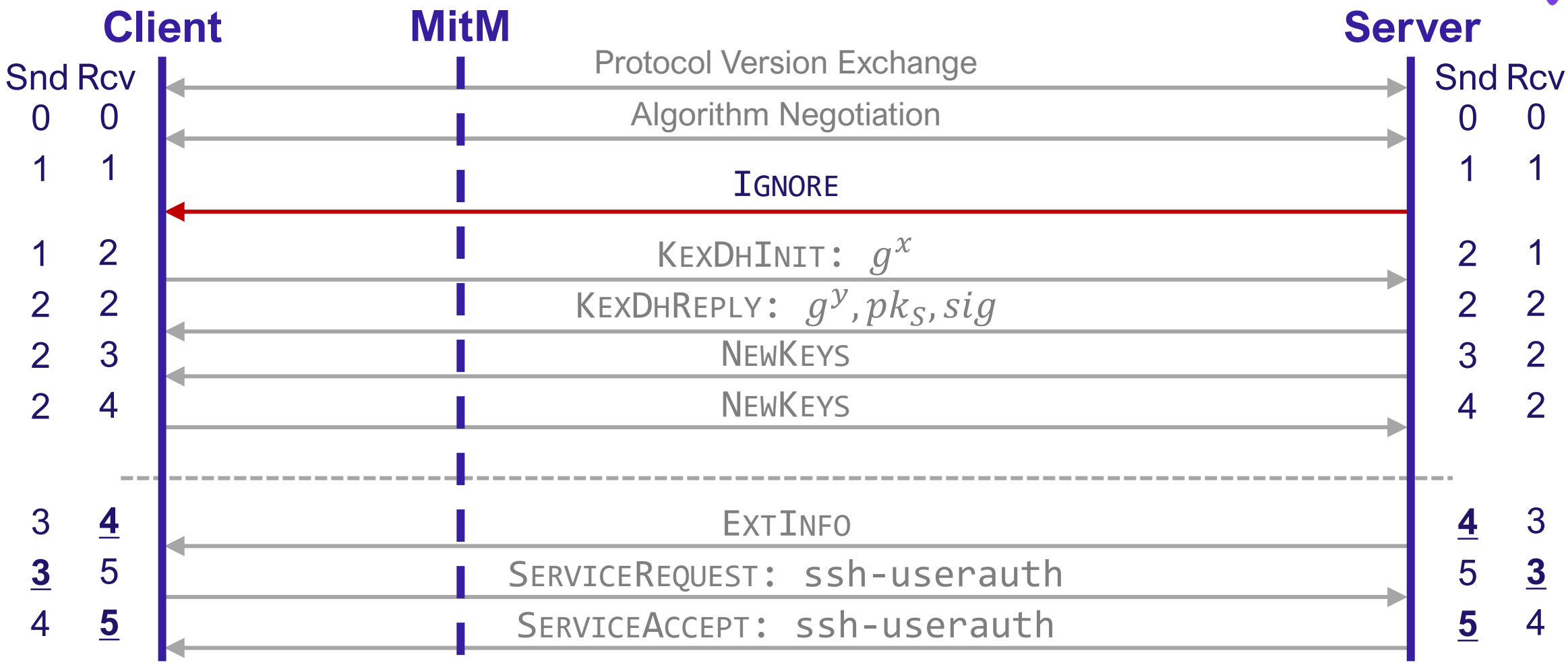
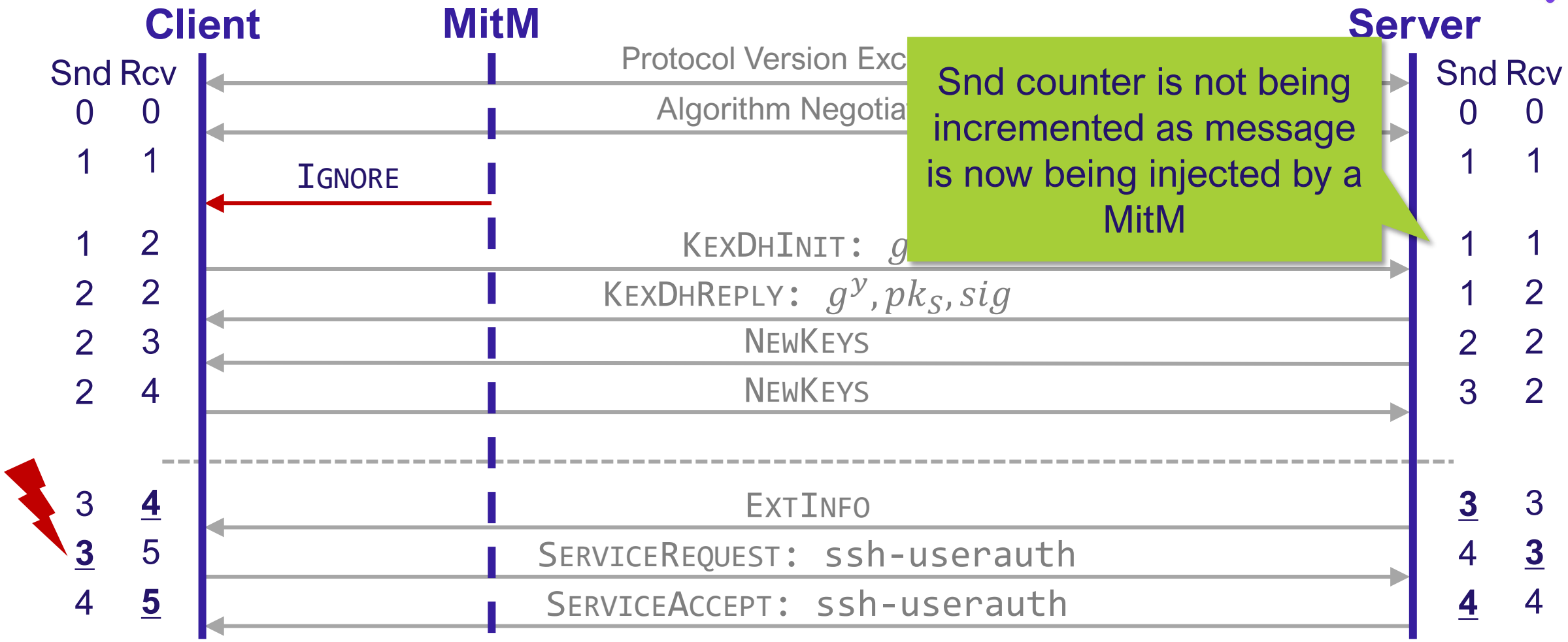
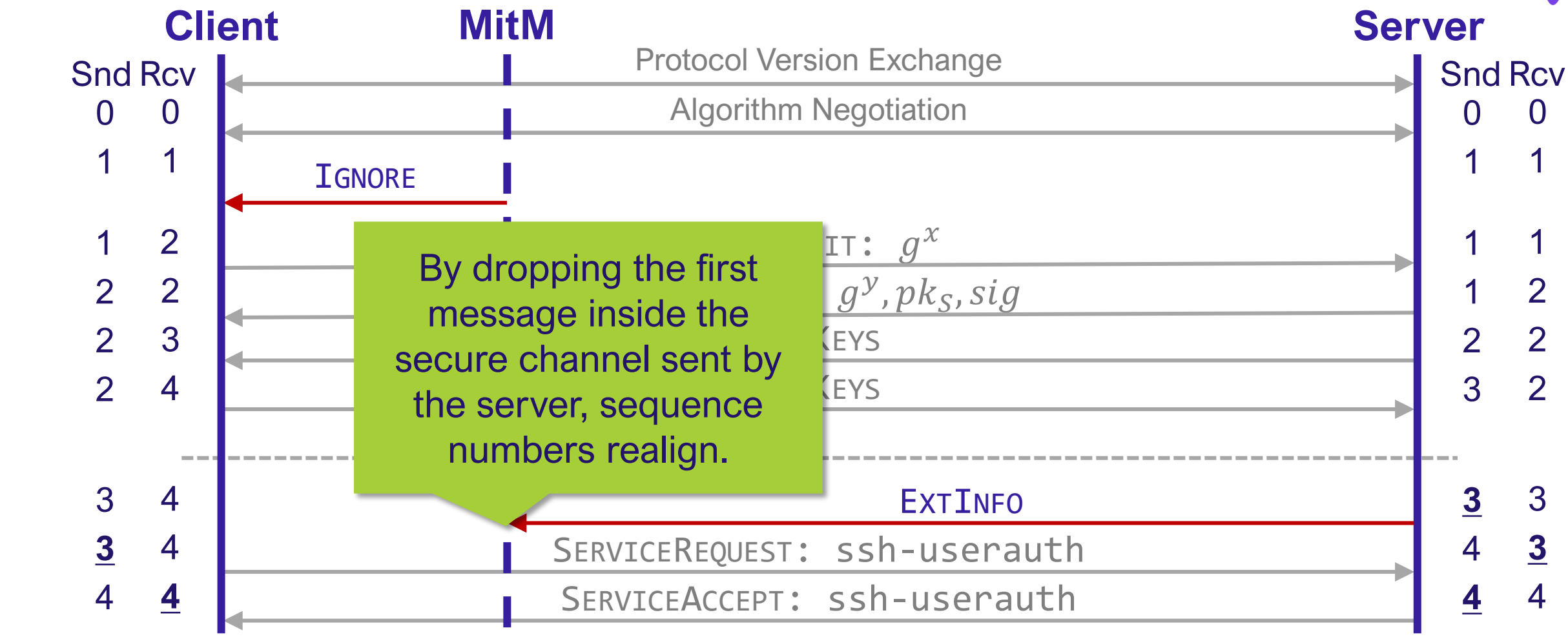




MitM Attackers Can Inject Messages Into Handshake…



… And Drop Messages Inside The Secure Channel



The ExtInfo Message Contains Extensions as Key-Value Pairs

server-sig-algs	ping@openssh.com	Other Extensions
• List of public key algorithms for user authentication • Enables RSA-SHA2 support	• Like Heartbeat extension in TLS • Can be used to obscure keystroke timings	• Not considered because no security impact

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Implementation Bugs and Terrapin

CVE-2023-46445
CVE-2023-46446

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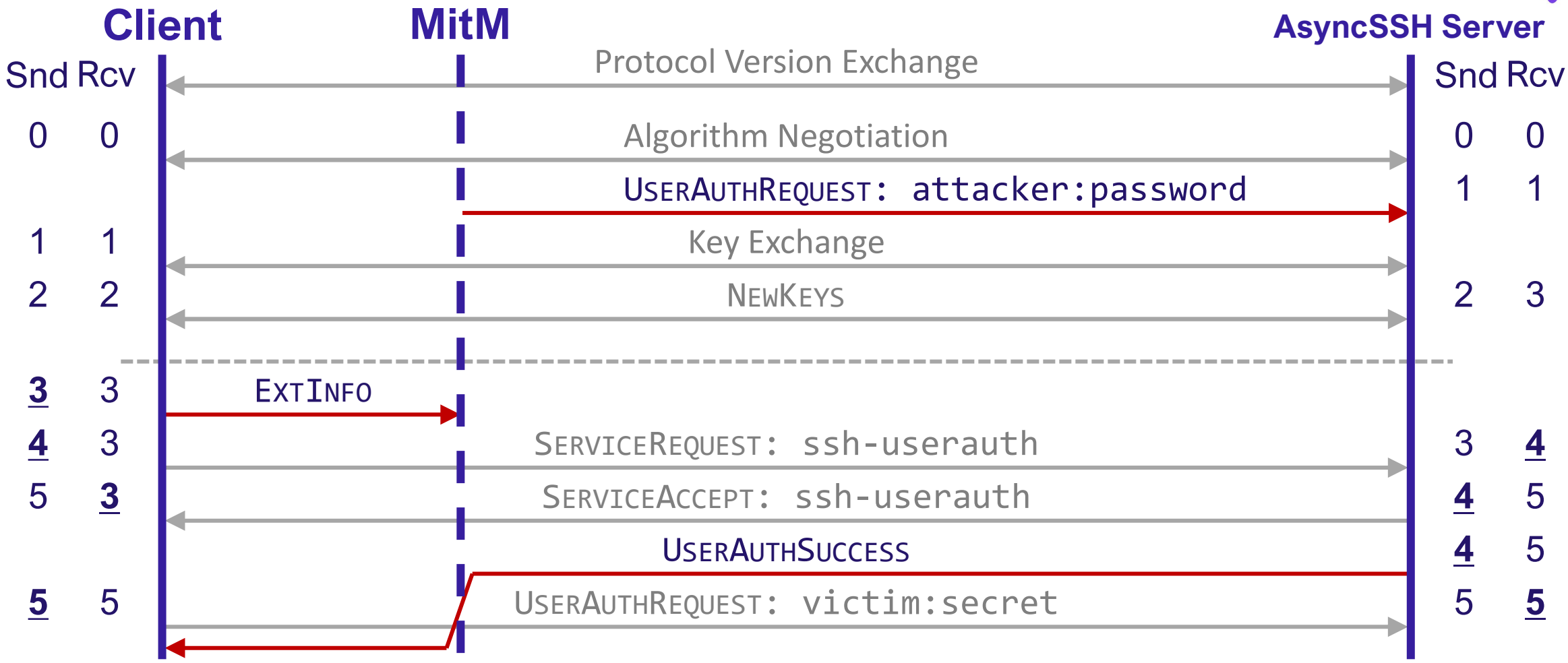
Implementation Bugs Can Escalate Impact



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Requirements and Countermeasures

ChaCha20-Poly1305 And Encrypt-then-MAC (EtM) Are Affected

Perfectly Exploitable

Exploitation Unlikely

Limited Exploitability

Success rate between 0.0003 – 0.8383

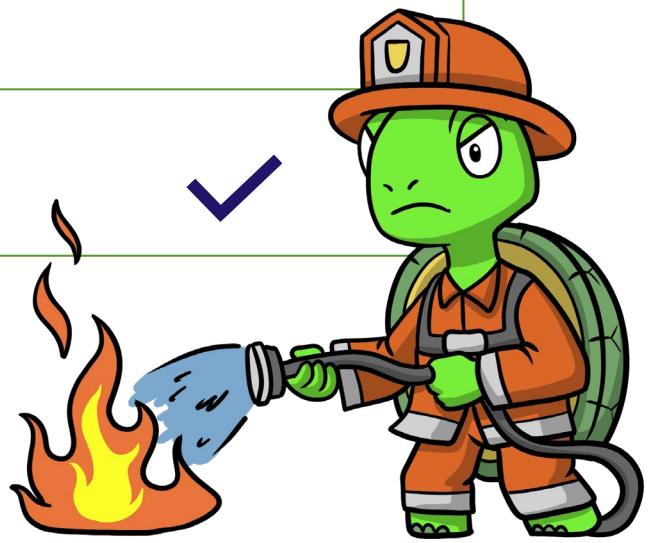
AE Mode	Preferred		Supported	
ChaCha20-Poly1305	8,739k	57.64%	10,247k	67.58%
CTR-EaM	3,964k	26.14%	4,200k	27.70%
GCM	1,219k	8.04%	10,450k	68.92%
CTR-EtM	828k	5.46%	10,685k	70.46%
CBC-EaM	359k	2.37%	1,585k	10.46%
CBC-EtM	14k	0.09%	2,614k	17.24%
Other	2k	0.01%	-	-
Unknown / No KEXINIT	36k	0.24%	-	-
Total	15,164k	100%		

Mitigating Our Attack Is Difficult

Countermeasure	Our Suggestion	"Strict KEX" (OpenSSH)
Reset sequence numbers at key installation	✓	✓
Authenticate the entire handshake transcript (hash)	✓	
Harden handshake to disallow unexpected messages		✓

> 30 unique implementations support "strict kex"

~ 11 million servers offer "strict kex"



Apply What You Have Learned Today

- Identify SSH servers in your organization
- Determine vulnerability to Terrapin and update accordingly
  - Basic vulnerability scanner available at https://terrapin-attack.com
  - No update available: Disable affected cipher modes
- Repeat this process for SSH clients!
  - Strict KEX requires support from client and server to take effect
  - A connection to a patched server can still be attacked if the client is vulnerable

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Thanks! Questions?

For more information:

https://terrapin-attack.com